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The Sleeping Child Burn—21 Years of Postfire Change

L. Jack Lyon

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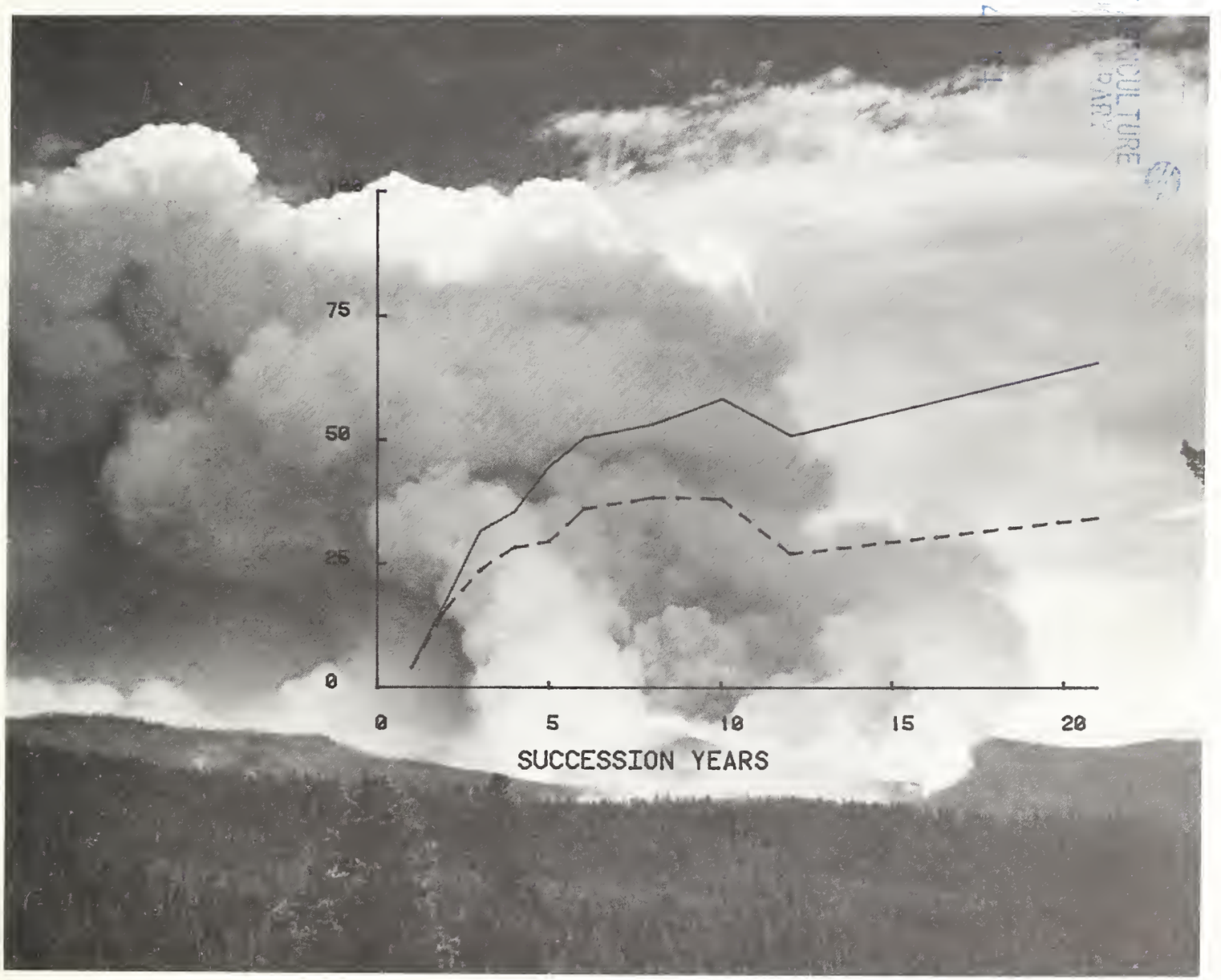

THE AUTHOR

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RESEARCH SUMMARY

For 21 years following the Sleeping Child Burn of 1961, vegetation development was periodically recorded on 11 permanent transects. Several cultural activities, including salvage logging, cattle grazing, and timber stand improvement thinning, influenced forest community development over short periods, but over a longer time we recorded a surprising stability and resilience in this lodgepole pine forest. Despite major modifications in plant community structure, it is possible to describe a consistent postfire successional pattern.

Long-term attrition of tree seedlings suggests a consistent progression toward 5,000 to 6,000 stems per acre (12 400 to 14 800 stems/ha) in about 30 years from any initial density between 5,000 and 160,000 per acre (12 400 and 395 000 stems/ha). Dominance appears to be established by the end of the first decade, but suppressed trees are extremely persistent.

Shrub communities in these lodgepole pine forests are relatively depauperate and slow to develop. Substantial deviations from a natural growth pattern were recorded as a result of cultural activities, but even in the absence of disturbance it requires at least a decade for the majority of shrubs to reach mature size.

Vascular cover of native herbaceous species increased from 1 to 2 percent in the first postfire year to 15 percent in the third year and 20 to 25 percent in the sixth growing season. Aerial seeding doubled these percentages, but actual cover values for the first two postfire years were still extremely low.

Snags in the Sleeping Child Burn fell at an annual attrition rate of 10 to 14 percent over 21 years, but rates were much higher for small stems, and the 7 percent of snags standing at the end of the study were mostly in diameter classes greater than 8 inches (20 cm).

A graphic model of postfire forest community development is presented. Within the restrictions imposed by subjective interpretation of available data, this model allows prediction of postfire tree seedling densities and long-term estimates of tree densities, shrub volumes, ground cover percentages, and snag densities.

The Sleeping Child Burn—21 Years of Postfire Change

L. Jack Lyon

INTRODUCTION

In early August 1961, more than 26,000 acres (10 500 ha) of upper montane and subalpine forest on the Bitterroot National Forest burned in a lightning-caused wildfire. At the time, the Sleeping Child Burn represented the single largest forest fire in the Northern Rocky Mountains in more than 20 years. Historically, large wildfires have not been uncommon in this region; but after two decades of successful forest fire suppression, the Sleeping Child was treated as an event almost without precedent. Not only was reseeding and rehabilitation an immediate concern, a substantial effort was invested in attempting to return the burned area to timber production. The burned area also provided an unusual opportunity to evaluate and describe vegetation recovery following a large and intense forest fire.

During the summer of 1962, we established 11 permanent transects designed to sample changes in vegetation structure and development. These transects were sampled annually through 1967 and in alternate years through 1973. At the end of 12 growing seasons, only two of the original transects had not been compromised in some degree by salvage logging, herbicide treatments, post or pole sales, road construction, or cattle grazing. Thus, when the first 12 years of postfire vegetation development were reported (Lyon 1976), the collected information did not represent undisturbed postfire forest succession. Nevertheless, and despite some fairly substantial short-term modifications, the data did demonstrate a vegetation development pattern showing recovery, relative stability, and the substantial resilience of these high-altitude forest communities.

By 1982, vegetation on the Sleeping Child Burn had completed 21 growing seasons. A young and vigorous lodgepole pine forest had replaced the herbaceous community that characterized the burned area during the first decade. Management activities to restore the area as a productive forest had continued, and in many areas the trees had been mechanically thinned. Many snags fell, and in some areas near the road the larger snags were removed for firewood. Although it is not possible to report undisturbed postfire successional development, the Sleeping Child Burn still provides an exceptional opportunity to examine changes in forest vegetation over time. With the passage of 21 growing seasons, the data also provide a tentative model of forest succession and an evaluation of the deviations from normality due to management related perturbations. I am indebted to Peter F. Stickney for the many hours spent recording vegetation data on hot, dry hillsides.

METHODS

Transects to sample vegetation in the Sleeping Child study consisted of 10 circular plots, 23.55 ft in radius (0.04 acre or 0.016 ha), with a paired 2- by 2-ft (0.6- by 0.6-m) plot located 10 ft (3 m) uphill from the circular plot center. Plot centers were spaced at 50-ft (15-m) intervals, and all plots were permanently marked with 3/8-inch (1-cm) steel pins. Most of these steel pins were still intact in 1982, and all data were taken at the same points originally sampled.

Circular Plots (0.04 Acre)

Vegetation sampling in the circular plots through 1973 included counts of all trees and shrubs over 6 inches (15 cm) tall and height and diameter measurements of up to 10 shrubs, by species, in each plot. In 1982, this sample was limited to measurement of all trees and shrubs over 18 inches (46 cm). In addition, the plot radius for trees was reduced to 16.65 ft (0.02 acre or 0.008 ha) to speed field sampling. Trees were classified as over 18 inches, over 4.5 ft (l.4 m), and over 8 ft (2.4 m) in height as a means of separating dominance classes. While fairly large numbers of trees under 18 inches appeared to be present on some transects, I assumed that these individuals were unlikely to have any impact on future development of the burned area. Shrubs were measured on two dimensions of the plant crown (a, b) and height (h). These data were converted to crown volume ($V = \pi abh/4$) to represent the space occupied by shrub crowns.

Two- by Two-Foot Plots

Data recorded in the 2- by 2-ft plots included all vegetation under 18 inches in height to the nearest quarter plot and frequency of occurrence for all plant species. Plant species not contributing a full quarter of cover were combined in a single category.

Summaries

In summarizing data, tree densities are expressed as numbers of stems per acre (stems/ha), shrub volume as ft^3 per acre (m^3/ha), and ground level cover as a percentage. As an aid to visualizing shrub terminology, we found that shrub volumes less than 2,500 ft^3 per acre (170 m^3/ha), unless concentrated in a few large alders or willows, do not produce an impression that shrubs represent a substantial component of the vegetation. If all shrub species are small, like vaccinium and spiraea, shrub volume must exceed 5,000 ft^3 per acre (350 m^3/ha) before producing a visual impression of shrub presence.

MANAGEMENT ACTIVITIES AND TREATMENTS

From 1962 to 1982, but particularly in the years before 1970, the Darby and Sula Ranger Districts conducted watershed rehabilitation, timber salvage, and timber stand improvement (thinning) programs in the Sleeping Child Burn area. Some Christmas tree sales, pole and firewood sales, and a mistletoe control project were carried out; and 400 to 900 cattle were grazed within the burned area each year. Two of these activities appeared to have a potential for producing long-term modification of forest communities in the burn. First, during the initial growing season, the entire burn was treated with an aerial seeding of domestic grasses and forbs. In addition, from 1966 to 1969, much of the burn was treated to prevent the spread of mistletoe, and a number of chemical thinning projects were conducted. Nearly 3,000 acres were treated directly, and a much larger area was affected by drifting herbicides from the treated areas.

In 1976, for the sample transects, direct crown kill amounted to about 623 ft^3 per acre (44 m^3/ha) of shrubs and 11 to 25 percent of the vascular cover on areas treated with herbicides. At the same time, and despite treatments that substantially reduced all forms of vegetation, even the most extreme deviation caused by the treatments was within the range of normal variation for the communities studied.

From 1973 through the end of this study, the Bitterroot National Forest conducted timber stand improvement programs on much of the burned area. In addition to the 10- to 14-ft (3- to 4.3-m) plantation spacing commonly used in this region, several areas were treated with an experimental "crop tree" thinning in which a circular plot was removed around a dominant tree. In many areas, snags were removed in deadwood sales for the house-log market. Cattle grazing continued within the burn, but the available forage resource declined and the number of cattle was reduced to less than 100. Many of the salvage logging roads of the 1960's were closed, but the Sleeping Child Burn remained a popular firewood gathering area for the residents of the Bitterroot Valley.

Toward the end of the study period, big game use of the area increased substantially, and both mule deer and elk were seen in the burned area.

Of the 11 transects established in this study, only one remained essentially undisturbed during the 21 years. Two additional transects were disturbed in only minor ways during the first 12 years and remained undisturbed after that time. Of the remaining eight transects, one was undisturbed until a deadwood sale (1980 to 1981); four others were influenced by aerial herbicide applications (1966 to 1969), but have since remained undisturbed; and three that were treated with herbicides (1966 to 1969) have since been thinned by mechanical means for timber stand improvement. Table 1 presents a brief summary of the disturbances and treatments influencing vegetation development on each of the transects during the two study periods: 1962 to 1973 and 1974 to 1982.

Table 1.—Disturbance and treatment summary for 11 Sleeping Child transects

Transect	1962 to 1973	1974 to 1982
SC01	No disturbance	No disturbance
SC02	No disturbance	Deadwood sale
SC04	Herbicide treatment	No disturbance
SC05	Herbicides, pole sale, cattle grazing	Thinning (crop-tree)
SC06	Herbicides, pole sale, cattle grazing	No disturbance
SC07	Herbicides, pole sale, cattle grazing	Thinning (crop-tree)
SC08	Herbicides, cattle	Thinning (plantation)
SC09	Herbicide drift, cattle	No disturbance
SC10	Herbicide drift	No disturbance
SC11	Herbicide treatment	No disturbance
SC12	Herbicide treatment	No disturbance

POSTFIRE VEGETATION DEVELOPMENT

The variety and combination of treatments received by different vegetation sampling transects in this study has virtually eliminated the use of statistics other than a few undemanding nonparametric tests. The treatments also made it difficult to determine habitat types for the burned-over plots. Keys to habitat type (Pfister and others 1977) are based on the presence of indicator species which, in this study, were invariably poorly represented and in many cases could have been influenced by the treatments. Habitat types represented in the 11-transect sample probably include *Abies lasiocarpa/Vaccinium scoparium* above 7,000 ft (2 100 m) and *Pseudotsuga menziesii/Vaccinium globulare* or *Pseudotsuga menziesii/Calamagrostis rubescens* on different aspects below that elevation.

In general, I have attempted to evaluate relationships demonstrated by the Spearman rank order correlation statistic, or to compare means of three or four transects receiving similar treatment. For some evaluations, transect SC01 has been deleted. This transect was on a severely burned north aspect at 7,200 ft (2 200 m). In several respects it cannot be considered representative of the burned area. Tree densities on SC01 were far lower than those on any other transect and, unlike all other transects, only 36 percent of the trees were lodgepole pine. Only one other transect had less than 90 percent lodgepole in the tree component.

By 1973 natural attrition of lodgepole pine was occurring at about the same rate produced by chemical treatments, and most of the shrub crown losses had been recovered. Vegetal cover had stabilized on most transects even though community structure had been substantially modified in some cases. In 1982 the Sleeping Child Burn gave the casual observer a general impression of a nearly homogenous lodgepole pine forest, but there were still vast differences among transects. Figure 1 shows representative photographs from three of the 11 transects studied.

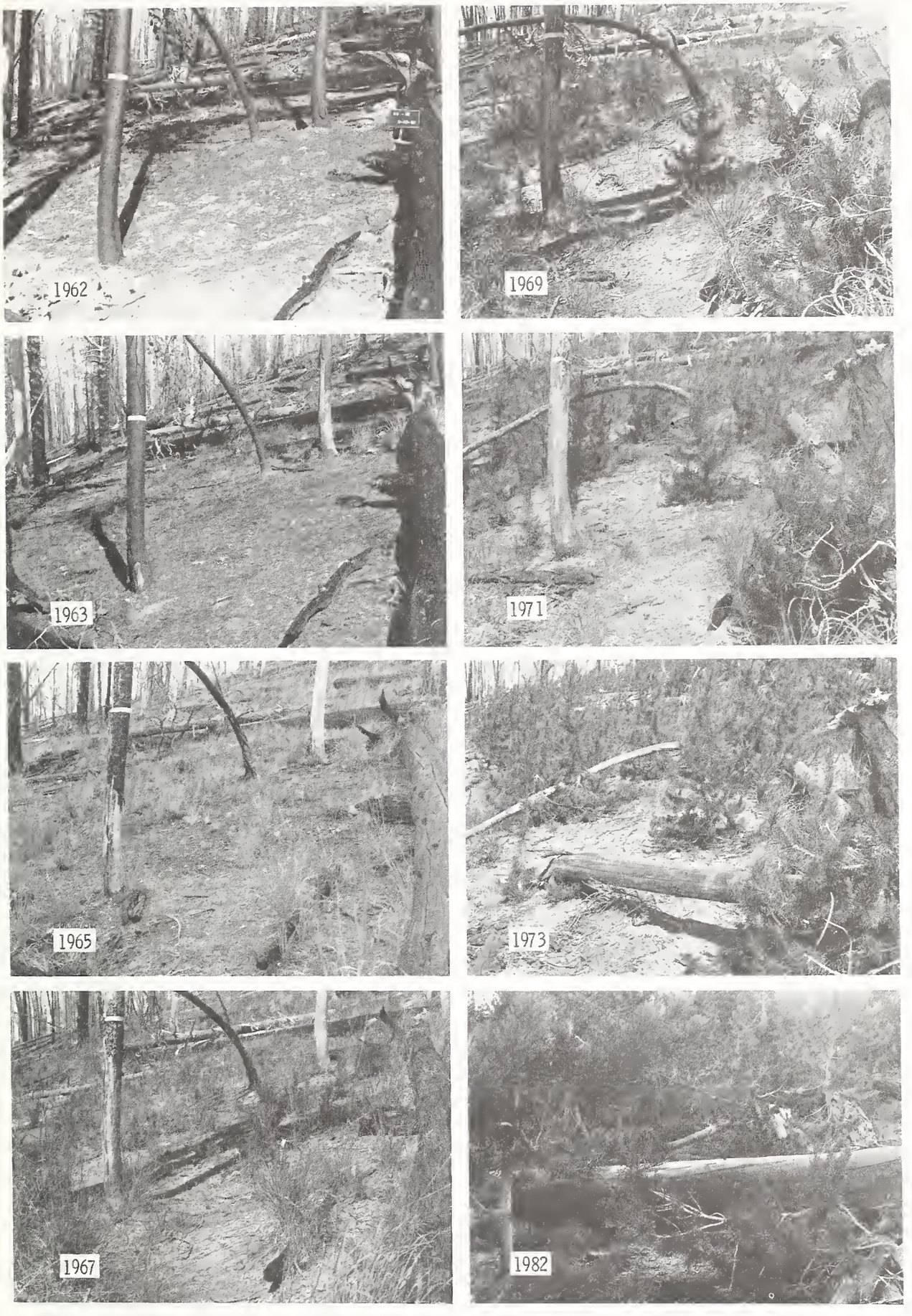

Figure 1.—Representative photographic display of three transects.

Figure 1.—(con.)

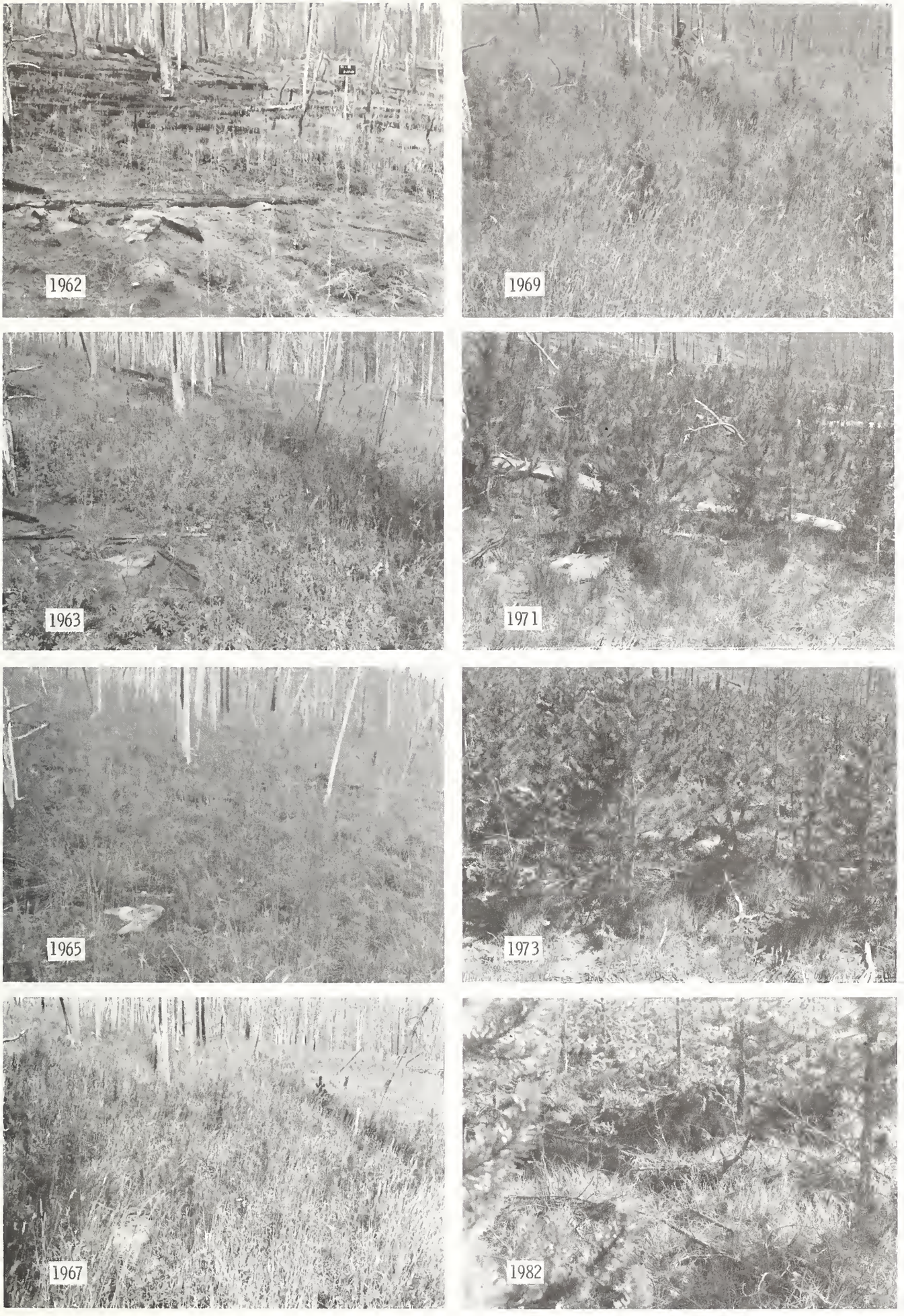

Figure 1.—(con.)

Changes in Tree Density and Dominance

In the initial years after the wildfire, tree seedling densities were as high as 159,000 per acre (393 000/ha) on some transects. The average for all 11 transects was over 34,000 per acre (84 000/ha). Annual attrition of tree seedlings from 1962 to 1973 was 5.77 percent, leading to a survival of 52 percent. Thus, while nearly half of the seedlings died during the first 12 years of study, the average density was still 17,700 live trees per acre (43 700/ha) in 1973. Of these, about 30 percent, or 5,350 per acre (13 200/ha), were over 18 inches (46 cm) tall and were considered likely to be the eventual dominant individuals. The Spearman rank order correlation between initial seedling density and surviving tree density was $r_s = 0.92$, and the correlation between initial density and percentage of survivors over 18 inches was $r_s = -0.90$. For the first 12 years, trees apparently survived in proportion to seedling densities but achieved dominance in inverse proportion to densities.

In 1982, live trees under 18 inches in height were not counted, but the number over 18 inches had only increased to 5,970 per acre (14 750/ha). Because 17,700 live trees per acre (43 700/ha) were present on these sites in 1973, the annual increment to dominance represents a conversion of less than half of 1 percent annually. Small trees that did not achieve dominance in this period will eventually succumb, but their tenacity is indicated by a Spearman rank correlation of $r_s = 0.85$ between seedling density in 1962 and tree density in 1982. Concurrently, there was a strong negative correlation between initial seedling densities and the percent of surviving trees over 8 ft (2.4 m) in height ($r_s = -0.65$). After 21 years, and in spite of some considerable management effort to modify the natural course of forest succession in these stands, trees were still surviving in proportion to immediate postfire densities, while the proportion of dominant trees was in inverse proportion to the level of competition.

Presumably, it will be a number of years before the remaining nondominant trees actually die, but by 1982 it was apparent that these repressed individuals represented little potential for increasing tree densities in the future. In the following discussions, I have assumed that small trees not measured in 1982 will have died by 1991. Thus, the calculated attrition rates and survival estimates presented here (5.9 percent annual loss and 34 percent surviving) are representative of probable tree densities to at least the end of the third decade.

In 1976 I reported that tree seedling attrition and survival on the four undisturbed transects (5.3 percent annually to 55 percent) were not significantly different from attrition and survival on the seven disturbed transects (5.8 percent annually to 52 percent). After 1973, however, only 14 percent of the trees on the undisturbed transects died, compared to 72 percent on the disturbed transects. Comparative annual attrition rates in the two groups were 0.8 percent and 6.9 percent. Potential explanations of the greater attrition rates on the disturbed transects include the possibility of a latent disturbance effect or herbicide influence. More likely, however, direct competition, as determined by tree densities, was responsible. More than five times as many tree seedlings were present on the seven disturbed transects in 1973, and I expected that reduced survival might be detected where competition was high. Disregarding all cultural treatments, for four transects with less than 10,000 initial seedlings per acre (24 700/ha), survival to 1982 was 36 percent, as compared to 31 percent on three transects with an average initial density of 22,000 per acre (54 400/ha), and only 13 percent on three transects with initial densities of 50,000 or more per acre (123 600/ha). On three areas treated with herbicides during the 1960's, attrition was 6.7 percent and survival 46 percent to 1973; but when these same areas were mechanically thinned, annual attrition increased to 16 percent and survival dropped to 20 percent from 1973 to 1982.

Among surviving trees, dominance was clearly established by about the 10th year of growth. The average number of trees per acre over 18 inches (46 cm) tall did not increase substantially in the second decade, and these trees probably represent most of the potential for eventual success. In 1982, only one transect had more than 1,000 trees per acre taller than 8 ft (2.4 m), and no transect had more than 8,500 trees per acre (21 000/ha) taller than 4.5 ft (1.4 m). At all densities greater than 6,000 per acre (14 800/ha), trees over 8 ft in height made up 4 to 9 percent of the population (average 6.3 percent). Below 6,000 trees per acre, the percentage of trees over 8 ft in 1982 was an exponential function roughly expressed: $\text{percent} > 8 = 6.3 + 2.2(6-D)^2$, where D = thousands of trees per acre.

Succession model.—If both the mechanical thinning and chemical influences are recognized, these data suggest an outline of a model for lodgepole pine seedling attrition and survival over a period of three decades. With initial seedling densities less than 10,000 per acre (24 700/ha), attrition will be a constant 3.5 percent for the total period. Survival to 30 years should be nearly 50 percent of initial densities.

For somewhat higher initial seedling densities, ranging up to about 25,000 per acre (61 800/ha), attrition will average 6 percent annually for the first decade and drop to less than 3 percent for the remainder of the period. Within this range, survival to 30 years should be 30 to 50 percent of the initial density.

With even higher initial densities, averaging 95,000 seedlings per acre, attrition in the first decade will be 6 percent. But as trees become larger the rate will rise to 7.5 percent for the second and third postfire decades. Survival to 30 years should be only 15 to 20 percent of initial densities.

In the absence of a better model, lodgepole pine forests on the Bitterroot National Forest will normally have 3,500 to 8,000 dominant stems per acre (8 650 to 19 800/ha) at the end of the second decade, and these trees will eventually stabilize at a density no higher than 5,000 to 6,000 stems per acre (12 400 to 14 800/ha).

Development of the Shrub Community

In discussing a forest community as depauperate of shrubs as the Sleeping Child Burn, it is difficult to assign much significance to changes in shrub volumes.

In 1973 only two of the 11 transects had shrub volumes approaching 5,000 ft^3 per acre (350 m^3/ha) and the average for all 11 Sleeping Child transects was 2,077 ft^3 per acre (145 m^3/ha). By 1982 three transects had shrub volumes over 5,000 ft^3, two transects were near 3,500 ft^3 (240 m^3/ha), and the overall average had nearly doubled to 3,983 ft^3 per acre (279 m^3/ha). While this increase appeared to be fairly substantial, it actually represented almost no change in the appearance of the Sleeping Child Burn. In 1973 over 50 percent of all shrub volume was recorded on a single transect, and in 1982 nearly 50 percent was recorded on only two transects. On the remaining nine transects the average shrub volume was 2,491 ft^3 per acre (174 m^3/ha); and on three of these transects, shrubs occupied 1,000 ft^3 per acre or less (70 m^3/ha).

Changes in shrub volume on individual transects between 1973 and 1982, illustrated in figure 2, were quite variable. Three transects demonstrated no change, three increased 100 to 200 percent, four increased 300 to 400 percent, and one had an increase in volume of over 1,000 percent. On the three transects with the majority of shrub volume (63 percent), the average increase was 54 percent between 1973 and 1982. On the eight remaining transects, the average crown volume for shrubs increased by about 230 percent in the same period. However, even though we recorded proportionately greater increases where initial volumes were low, the average volume in 1982 reached only 2,038 ft^3 per acre (143 m^3/ha) on these transects.

In my earlier paper (Lyon 1976), I indicated that additional shrub volumes of 623 ft^3 per acre (43 m^3/ha) would probably have developed on the seven transects treated with herbicides. By 1973, indications were that most of this shrub crown loss would eventually be recovered through regrowth, but almost no evidence indicated that any of the dominant shrub species had been permanently removed from the forest community.

The 1982 comparison of seven chemically disturbed transects with four undisturbed transects shows an increase in shrub volumes of 84 percent versus 178 percent. However, only one of the undisturbed transects had more than 1,100 ft^3 per acre (80 m^3/ha) of shrub volume, and other evidence suggests little likelihood that herbicide treatments had much influence on the differences in shrub volumes. Among the seven treated transects, four remained undisturbed after chemical treatments in 1969. On these transects, shrub volumes increased 63 percent. The remaining three transects were thinned mechanically between 1973 and 1982, and shrub volumes increased by 260 percent.

Shrub responses on the three thinning areas somewhat obscured the potential for evaluating competition between trees and shrubs, but if thinned areas are deleted from analysis, the three areas with the greatest tree densities in both 1973 and 1982 produced shrub volume increases only 50 percent as great as increases on four areas with lesser tree densities.

On the other hand, the Spearman rank correlation between tree densities in 1973 and shrub volumes in 1982

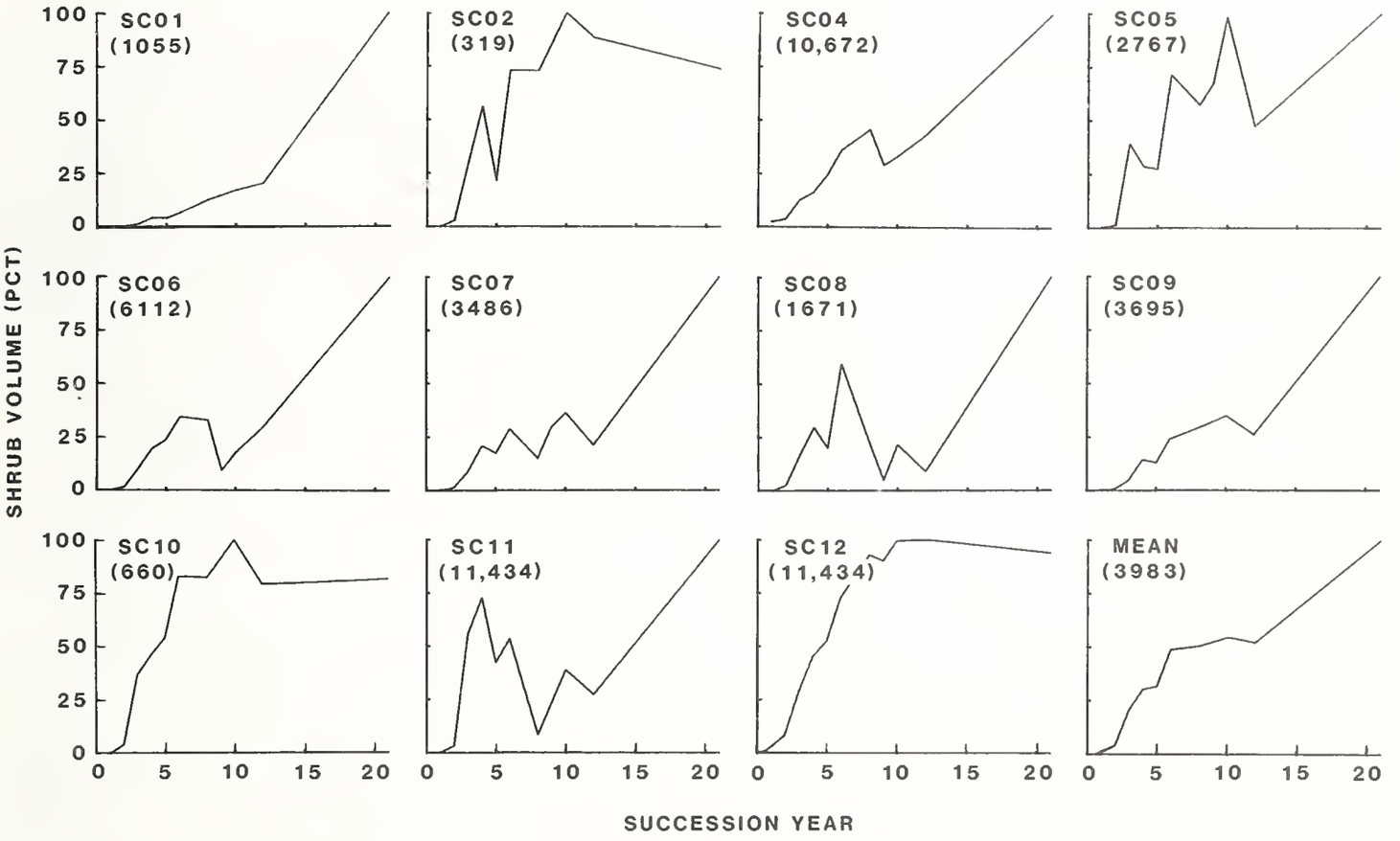

Figure 2.—Shrub volumes on individual transects.

was $r_s = 0.47$, and the correlation between 1982 tree densities and shrub volumes was $r_s = 0.41$. Because both these coefficients are positive, it appears that direct competition between trees and shrubs may not be particularly significant in determining the structure of these plant communities.

Species performance.—In attempting to develop a predictive model for changes in shrub volumes over time, it was necessary to examine the performance of individual species rather than communities on transects. Growth patterns described by transect totals from 1966 to 1969 are relatively erratic (see fig. 2) for a number of reasons. Several of the 16 shrub species[1] identified during this study were susceptible to chemical treatments while others remained almost unaffected. On transects, relatively minor changes in the volume of a few large shrubs obscured any changes in smaller plants, and precipitation in April caused substantial year-to-year differences in average sizes of at least two small-shrub species (Lyon 1976).

Of the shrub species detected during this study, nine were recorded in sufficient numbers to allow evaluation of year-to-year changes in average size. Of the remaining seven, specimens of SARA, RIVI, RILA, VAMY, and SOSC were found on several transects, but in low numbers; SYOR was recorded on one transect until killed by herbicide sprays in 1969; VASC, where present, was almost always too small to be counted under the 6-inch (15.2-cm) height limitation.

For two species, ALSI and LOUT, fewer than 10 specimens were encountered, but the same plants were involved in all measurements. Sample sizes for the other species range from under 50 plants of AMAL each year to 50 to 150 annually for ROGY, SASC, SHCA, and MEFE, and 300 to 400 for SPBE and VAGL.

Examined in the raw data (fig. 3), year-to-year performance of individual shrub species generally confirms the erratic performance on transects. Six of the nine species (ALSI, SASC, LOUT, MEFE, ROGY, AMAL) demonstrated sharp declines in average size at some time between 1966 and 1969. ALSI and LOUT appeared to recover from the chemical spray effects in a single growing season, but the other species remained depressed for several years, and ROGY may never have recovered. If responses to herbicides by SHCA, SPBE, or VAGL occurred, it is not clearly demonstrated in these data as a deviation greater than the normal variation around a generally increasing average.

Succession model.—In attempting to describe undisturbed growth patterns for these nine shrub species, I have assumed that the greatest average size attained during 21 years is probably representative of the size that would have been reached in the absence of mechanical or chemical disturbance. I have further assumed that patterns of growth established before 1966 are descriptively normal, and that any negative deviation recorded between 1966 and 1969 would probably not have occurred in the absence of treatments. Given these assumptions, the predicted growth forms for nine common woody shrubs of the Sleeping Child Burn area are presented in figure 4 as a percentage of maximum size attained.

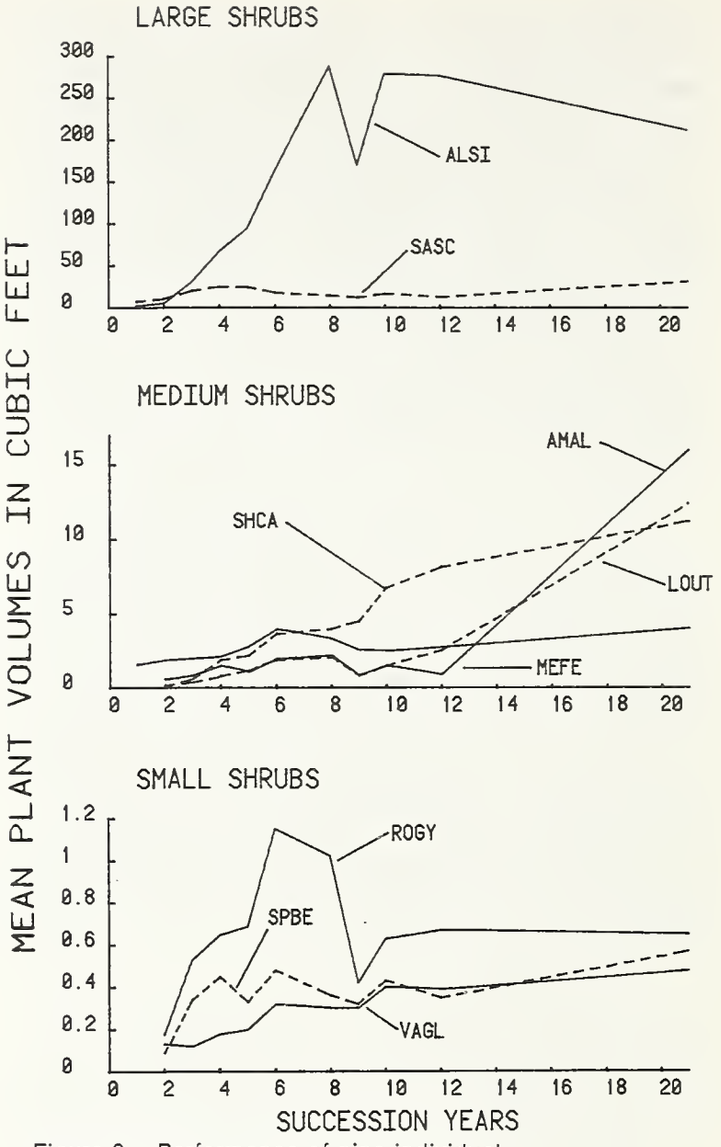

Figure 3.—Performance of nine individual shrub species.

Data points in figure 4 do not provide a good demonstration of the real differences in representative shrub sizes. VAGL, with 0.48 ft^3 per plant (0.013 m^3/plant), was the smallest of the nine species represented here; ALSI was the largest at 289 ft^3 (8 m^3). SASC, which is often considered a large shrub, was nearly an order of magnitude smaller than ALSI, and none of the other species examined averaged even half the volume of an average SASC.

Despite these substantial differences in individual plant sizes, the nine shrub species in figure 4 appear to describe only a few general patterns of growth over time. SASC and MEFE both recovered crown volume on root crowns that were apparently undamaged by fire. For these two species, over 25 percent of eventual crown volume developed in the first postfire growing season, and more than 50 percent was attained in the first 3 years.

[1]In the discussions of this section, I have used the four-letter species designations for shrubs. Each name consists of the first two letters of the genus and the first two letters of the species. The appendix is a summary list of all species mentioned in the Sleeping Child Burn studies.

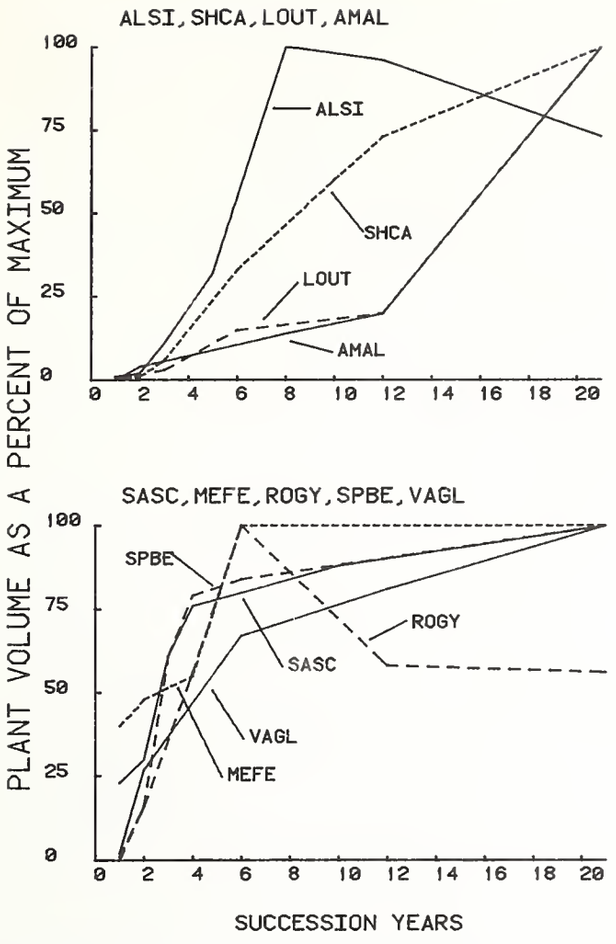

Figure 4.—All shrub species as a percentage of maximum reached.

A similar pattern was seen in ROGY, SPBE, and VAGL, except that initial growth was delayed until the second growing season and 50 percent volume was not reached until 3 to 5 years had passed. The growth curve for SPBE, however, is steeper than the curves for ROGY and VAGL. Of these three species, only ROGY resprouts from a root crown. The others have rhizomes and resprout from any unburned node.

ALSI and SHCA, although both resprout from root crowns, demonstrated a third and even more delayed growth pattern in which 4 to 5 years were required for 25 percent of eventual crown size to be attained. After the fifth growing season, ALSI expanded far more quickly than SHCA and then declined in size through the second decade. Unfortunately, this particular part of the growth curve is within the period of chemical applications, and the described pattern might reflect the response to herbicides.

Finally, LOUT and AMAL demonstrated a slow development pattern in which less than 25 percent of eventual volume was attained during the first decade. This same slow rate of increase was continued through the second decade. The effects of herbicide applications could be involved in this pattern, but the sample sizes, especially for LOUT, are small; and it was possible to evaluate the performance of specific plants to confirm that the pattern is consistent on transects where there was no exposure to herbicides.

Vegetal Cover

From 1973 to 1982, average vegetal cover at ground level increased from 51 to 66 percent on the 11 sample transects (table 2). This apparent 15 percent increase is deceptive, however, because over half the increase was in moss and lichen cover; and there was only one transect on which vascular cover was greater than had already been recorded some time prior to 1973. With minor exceptions, the graphic presentations in figure 5 suggest that development of vascular cover may have stabilized after about the sixth postfire growing season. Vascular cover declined by 7 percent between 1971 and 1973 as a result of the loss of introduced grasses, but a subsequent increase in native vascular plants was equivalent to this loss, and vascular cover in 1982 was only slightly different from vascular cover in 1967.

In my 1976 report, I attributed some significance to the fact that vascular plants represented 85 percent of total cover on four undisturbed transects, while mosses and lichens contributed over 50 percent of the cover on the remaining, chemically disturbed, transects. From 1973 to 1982, vascular cover increased by an identical 7 percent in these two groups of transects. However, moss and lichen cover increased by more than 20 percent on the undisturbed transects and not at all in the disturbed areas. The result was that by 1982 both groups were nearly 50 percent vascular and close to the

Table 2.—Percentage vegetal cover, average for 11 transects, 1962 to 1982

Source	Year									
	1962	1963	1964	1965	1966	1967	1969	1971	1973	1982
All vegetation under 18 inches	4.1	17.7	31.8	35.7	44.5	50.5	53.2	58.2	50.8	65.7
Vascular vegetation	4.1	16.1	23.9	28.4	29.6	36.1	38.2	38.0	27.1	34.1
Introduced species	2.7	9.0	10.6	12.0	12.6	14.5	13.8	13.3	4.7	.6
Perennial grasses	2.2	8.2	10.4	12.0	12.6	14.5	13.8	13.3	4.7	.6
Annuals	.6	.8	.2	—	—	—	—	—	—	—
Native species	1.4	7.1	13.3	16.4	17.0	21.6	24.4	24.7	22.3	33.7

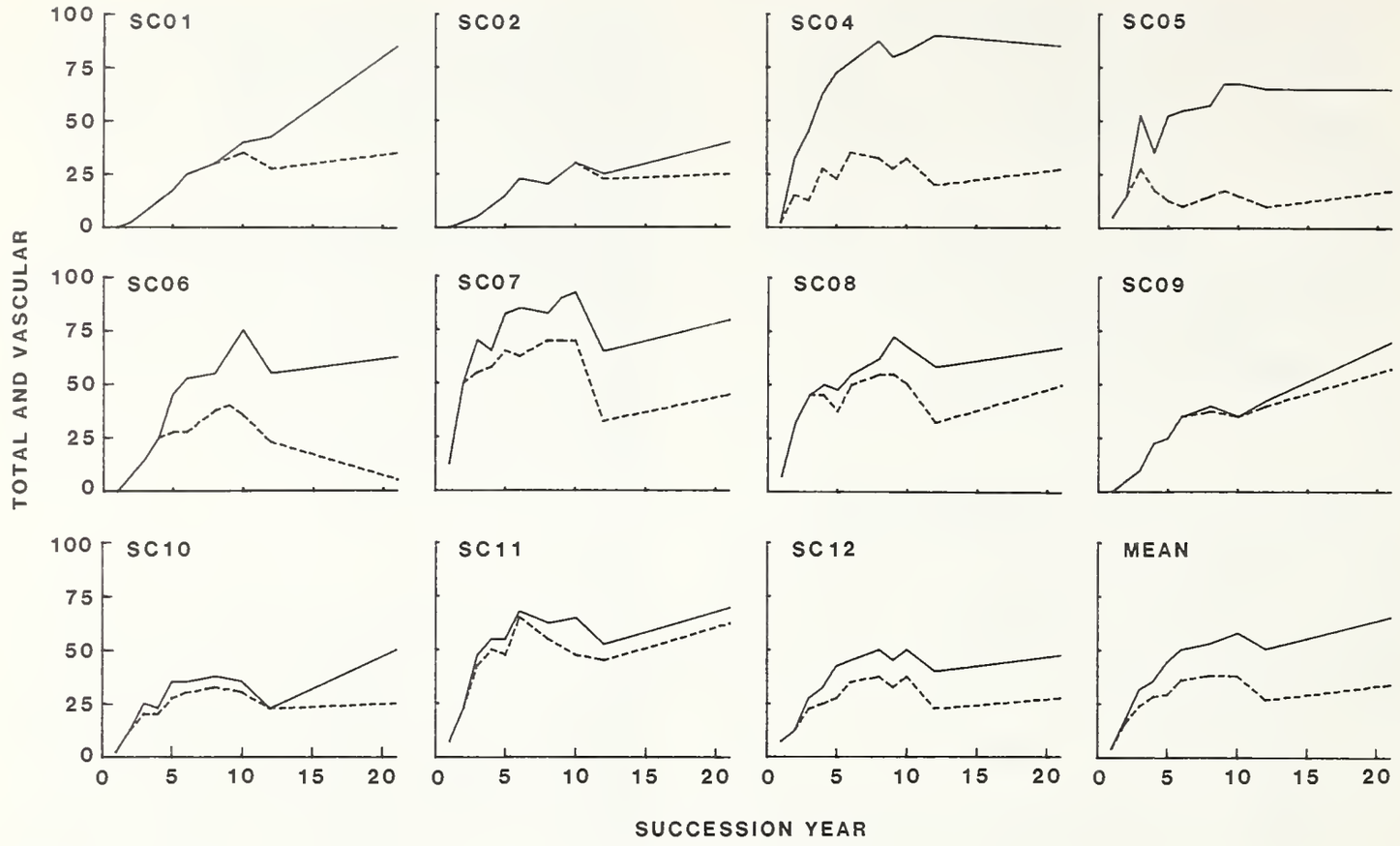

Figure 5.—Herbaceous cover, total and vascular, all transects.

overall average of 34 percent vascular cover. Any structural modification of ground-level vegetation related to herbicides was apparently assimilated in these plant communities.

In examining the data for other possible relationships affecting vegetal cover, I found that a strong influence was apparently exerted by trees. Vascular cover on four transects with fewer than 2,000 trees per acre (4 900/ha) in 1982 was over 50 percent, while seven transects with more than 3,000 trees per acre (7 400/ha) averaged less than 25 percent vascular cover. The Spearman rank correlation between tree density and vascular cover was $r_s = -0.70$, while the correlation between tree density and nonvascular cover was $r_s = 0.53$.

To evaluate the performance of individual species in the ground-cover layer (table 2), I repeated the calculations of 1976 in which all vegetal cover less than one-fourth plot was proportioned among the species present on the basis of plot frequencies. This calculation probably overestimates grass cover and underestimates forbs and small shrubs, but trends are represented consistently. The actual percentages involved are so small that no meaningful error is considered likely. A total of 43 vascular plant species were identified in the sample plots in 1982, but only 20 of these produced more than 0.5 percent cover on at least one transect, and eight of the 20 were found on fewer than five transects. Thus, only a few species could be examined individually for response to disturbances and prediction of growth patterns.

In both 1982 and 1973 VASC was the most ubiquitous plant species in the burn, and the only species other than lodgepole pine detected on every transect. Cover of VASC ranged from 1 to 33 percent and averaged 10 percent on 11 transects. This range is somewhat greater than was recorded in 1973, when every transect had at least 0.7 percent VASC cover and the mean for all transects was 4 percent. One substantial reason for the range of values recorded is seen in the continuing negative response of VASC to virtually any kind of vegetation manipulation. In 1973 four undisturbed transects had 10 percent VASC cover, while seven disturbed areas had only 1 percent. One of these disturbed areas was in a pole sale, and all had been influenced by herbicides. Although VASC cover had doubled by 1982, to 20 percent on the undisturbed areas and 3 percent where disturbed, there is little evidence that cover lost in the disturbances will ever be entirely replaced. Disturbances after 1973 were also calamitous for VASC. Three transects that remained undisturbed for 21 years had 16 percent VASC cover, four transects undisturbed after 1973 had 6 percent VASC cover, and three transects on which timber stand improvement was conducted after 1973 had an average of only 0.3 percent VASC. Only one transect that was ever disturbed has developed more than 6 percent VASC cover, while no undisturbed transect has developed less than 10 percent.

LUSU was detected on eight transects and provided cover in excess of 12 percent on three transects in the period before 1969. Following the herbicide applications, LUSU disappeared from two transects and declined from over 3 percent to less than 0.5 percent average cover on all transects. By 1982 LUSU had disappeared from three

more transects and had recovered to only 9 percent on the three transects where it was still present. Clearly, LUSU is a species with virtually no tolerance for herbicides and no capacity to recover from herbicide treatments.

XETE was detected on all 11 transects in 1973, but was only found on eight in 1982. Average cover of XETE for all transects apparently stabilized at 2 to 3 percent at the end of the first postfire decade, and has remained at that level independent of other plant community changes.

CARU was detected on seven transects in 1982. It is an important cover species on five transects, including four where it averaged 12 percent cover in 1973. On the four transects of best development, CARU cover had increased to 19 percent in 1982. Throughout the burn, CARU cover increased from 4 to 8 percent. There is no suggestion in any of the available data that CARU was influenced by any particular factor other than the fact that the four transects on which it reached greatest development are located between 6,700 and 7,000 ft (2 000 and 2 100 m).

EPAN has apparently continued to exist as a more or less sporadic presence throughout the burn area. Contrary to the overwhelming dominance sometimes seen in other forest types (Stickney 1980), EPAN has never been recorded with more than 3 percent cover on any transect in the Sleeping Child Burn. It was recorded on seven of 11 transects in 1982. The best development coincided with the most recent disturbance, but the average EPAN cover for all transects remained fairly consistently around 0.5 percent after about the third postfire growing season.

The three species of carex—CARO, CAGE, and CACO—developed to an average 2 percent cover in the burn in the eighth postfire year, and have remained at that level. CARO was detected on 10 transects in 1982 and is the most widespread of the three species. Carex species reached the greatest development on two easterly aspects where 11 percent and 4 percent cover was recorded in 1982. The data do not suggest that carex development was modified by cultural disturbance.

Only four other vascular species exceeded 0.1 percent cover and were recorded on more than four transects in 1982. All were introduced in the aerial seeding for watershed protection immediately after the fire. Of the six species included in the mixture, two had virtually disappeared by the fourth growing season. SECE and TRRE briefly produced about 1 to 2 percent cover in the early postfire years, but thereafter failed to survive or reproduce.

The more successful species in the seeded mixture were all perennial grasses. Of these, DAGL appeared to be the most successful during the first postfire decade. However, DAGL declined drastically in response to two dry seasons before 1973, and has declined continuously from 9 percent cover in 1967 to 2 percent in 1973 and 0.1 percent in 1982.

FEOV was the second most successful seeded grass during the first decade in that it reached 2 percent cover by the second year and then remained at that level. Although FEOV was still present on 10 of the 11 transects in 1982, it had declined to 0.2 percent cover in the burn. PHPR also produced cover in the 2 to 3 percent range for several years, but dropped below 2 percent in 1966 and continued to decline to 0.7 percent in 1973 and to a trace on five transects in 1982.

Of the seeded perennial grasses, BRIN originally appeared to be the least successful. It never exceeded 1 percent cover and remained below that level during the entire study. However, BRIN is apparently persistent. In 1982 it was still present on six transects and produced 0.3 percent cover.

Species Frequencies

Plant communities in the Sleeping Child Burn are relatively uncomplicated. Even the most complex transects contained fewer than 20 species in the 10 small sample plots. The average transect had 20 vascular species made up of 11 herbaceous plants, seven shrubs, and two trees. Only one transect had more than 25 species, and none exceeded 30. Considering only those species recorded in the small plots, an average nine species were recorded 1 year after the fire, 14 species were recorded in the eighth growing season, 13 in the 12th season, and 15 in year 21.

Excluding trees and shrubs, herbaceous species recorded in the small plots can be combined in six plant groups to provide an illustration of long-term trends. Figure 6 expresses the average combined frequency of occurrence for six plant groups on 11 transects as the probability of finding any representative of the group in a random sample plot. Probability can exceed 1.00 when two or more representatives of the same group are commonly found in plots.

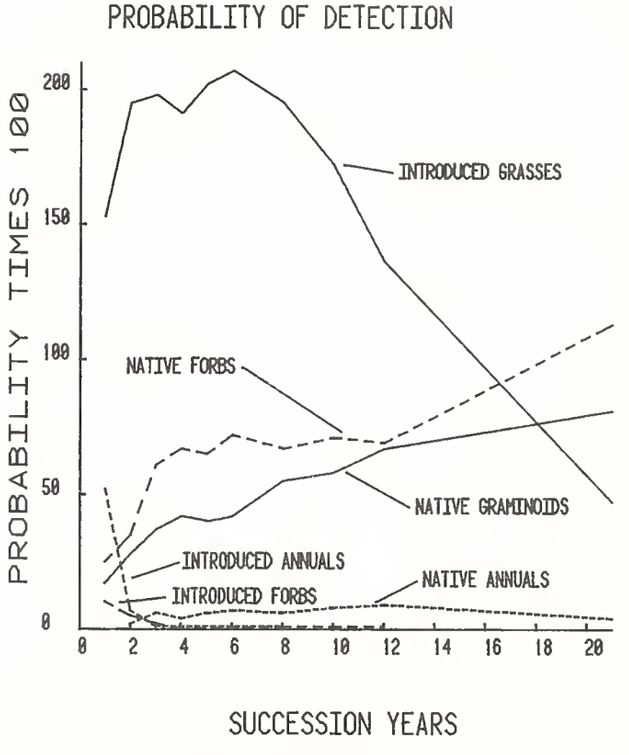

Figure 6.—Probabilities of occurrence in sample plots for six plant groups.

These probability data indicate several significant trends and demonstrate some changes in community composition that were only partially defined after the first 12 postfire years. Trees and shrubs, as well as the plant groups illustrated in figure 6, had nearly stabilized by the fourth growing season. Following stabilization, native graminoids increased at a slow but consistent rate of about 2.4 percent each year. By 1982 they were found in more than 80 percent of the plots. On the other hand, the introduced grasses were found in plots at a probability exceeding 1.00 for more than 12 years, but declined continuously from about the sixth growing season to a probability less than 0.50 in 1982. Although no longer important as cover, these species were still common throughout the burn at the end of the study.

Introduced annuals and forbs both disappeared from the sample plots by the third year and native annuals maintained a low, but relatively consistent, probability below 0.10. Native perennial forbs appeared to have stabilized at about P = 0.70 during the first decade, but over the second decade increased to appear in nearly every plot.

Succession model.—The frequency data illustrate a slow, long-term increase in native forbs and graminoids and confirm the persistence of introduced grasses. All changes are gradual, however, and it appears that herbaceous cover estimates of the fourth postfire succession year will adequately describe trends for at least 20 years in these forest communities.

Ecological Effects of Disturbances

Throughout these presentations of tree, shrub, and vascular cover changes over time, it was apparent that management related disturbance had a substantial influence in the development of forest communities in the Sleeping Child Burn. At the same time, comparisons of disturbed and undisturbed transects suggested that these communities are resilient. In most cases the disturbance produced a diversion from an apparently established path rather than a long-term permanent change. Trees and shrubs, in particular, appeared to recover from the disturbances of the first decade and to reinstate those community structures that might have been expected in the absence of disturbance. At the same time, and despite the relative tolerance of the larger woody species to various kinds of disturbance, some permanent changes occurred in smaller perennials in the ground-cover layer. On a few transects, and particularly as a result of mechanical influences, cover of VASC was reduced below levels recorded prior to disturbance and has remained low. LUSU was also reduced, or completely removed, from every community in which it was detected.

The influence of aerial seeding in the Sleeping Child Burn was also important in the first decade. For at least 10 years, the seeded species contributed significantly to ground-level cover. Competition from seeded species produced some reduction of lodgepole pine seedling densities during the first few postfire years, and seeded species may also have retarded the growth of native vascular plants.

In retrospect, it is hard to attach as much significance to these changes as I did in 1976. The loss of LUSU, because the species is a nitrogen fixer, may be a change that has ecological significance. Otherwise, at the precision level of this study, it is not possible to demonstrate any change greater than a short-term replacement of native graminoids by introduced species and a more permanent substitution in which the less tolerant native vascular species have been replaced by the more tolerant native species. Apparently, even relatively simple forest communities could assimilate perturbations of the kinds reported here. Possibly as important as the ecological questions are the economic evaluations that would determine whether manipulations of these forest communities produced beneficial results in long-term forest management.

DENSITY AND ATTRITION OF SNAGS

In the immediate postfire sampling period, snag densities on the Sleeping Child Burn averaged 497 per acre (1 230/ha). Because the majority of these snags were dead lodgepole pine, some direct correlation was expected between snag density and tree seedling density. However, this did not prove to be true. The three transects with the highest snag densities produced only medium density tree stands, and the two transects with the lowest snag densities produced the highest seedling densities. The Spearman rank order statistic for snag density and seedling density was $r_s = 0.10$ for the 11 study transects.

With a sample involving only 11 transects, development of a predictive model for postfire tree seedling densities is speculative. However, the available data strongly suggest that wherever snag densities exceed 200 per acre (500/ha), sites on aspects between azimuth 290° and 45° at elevations between 6,500 and 6,800 ft (2 000 and 2 100 m) are likely to have much higher seedling densities than sites outside that range.

From 1962 to 1976, snags on eight transects remained undisturbed by other than natural causes. For 2 years, less than 2 percent of these snags fell, but over the next 13 years, 85 percent fell at an annual attrition rate of 13.4 percent (Lyon 1977). Snags on one transect were removed in a deadwood sale before 1982, but data from the remaining seven transects indicate the attrition rate had declined to 10.8 percent after 1976, and nearly 93 percent of all snags had fallen in 21 years (table 3 and fig. 7).

An average attrition rate between 10 and 14 percent is somewhat misleading because snags under 3 inches (8 cm) went down at a much higher rate than the larger stems. After two seasons of less than 1 percent annual loss, attrition of small stems averaged 27.9 percent annually for 13 years and 25.9 percent through the 21st year. Snags 3 to 8 inches (8 to 20 cm) in diameter were slightly more persistent, but fell at a nearly constant rate of 8.4 percent through the 15th year and at 11.1 percent through 1982. Snags larger than 8 inches fell at an annual rate of 8.6 percent through 1976 and 8.3 percent thereafter. Attrition for these larger snags was

Table 3.—Numbers of snags per acre on sample transects by year of count

Transect	Year						
	1962	1963	1966	1969	1971	1976	1982
SC01	498	498	393	343	333	258	183
SC02	390	383	188	160	123	73	
SC04	423	413	190	145	110	68	20
SC08	240	240	148	83	38	15	10
SC09	693	685	403	268	203	75	25
SC10	918	918	358	160	95	28	5
SC11	570	565	265	170	108	35	3
SC12	243	223	198	160	118	53	23
Average	497	490	268	186	141	75	38

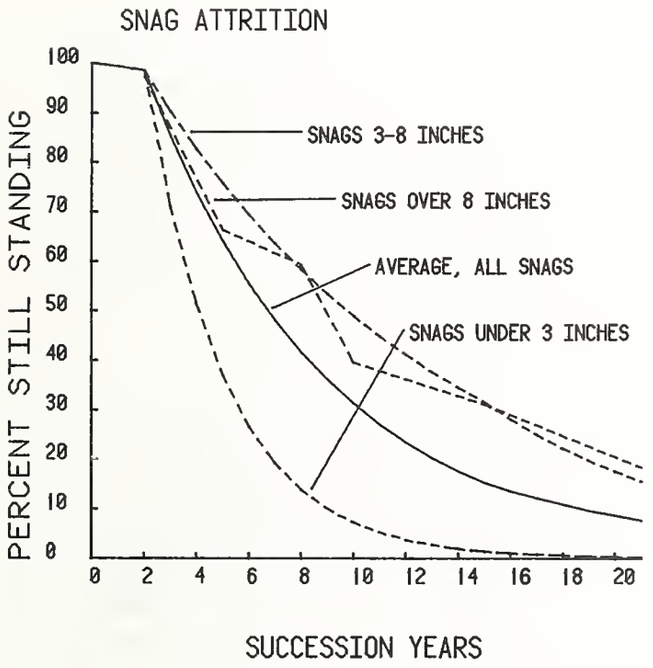

Figure 7.—Percentage of snags still standing, by year and diameter class.

characterized by sporadic blowdown rather than consistent annual losses. Within the small sample of stems over 12 inches (30 cm), the annual attrition rate was only 5.4 percent from 1976 to 1982.

POSTFIRE SUCCESSION MODEL

In this section I have combined all the preceding data summaries and discussions into a model describing postfire vegetation development on the Sleeping Child Burn. The described changes in postfire community structure are based on averages and probabilities derived from the 11 transects, and a considerable subjective judgment concerning the probable course development might have taken in the absence of herbicide treatments, seeding of exotic grasses, and timber stand thinning projects. Where possible, I have indicated a range of values associated with each graph. Although this model could be used in a predictive sense, the assumptions made and the limits of the data base require that it be considered a purely descriptive model for a specific situation and a limited range of habitat conditions.

Tree Densities

Following a crown fire in the mature forest, initial tree seedling densities were expected to be a direct function of lodgepole pine snag densities. However, there was little relationship between snag densities and seedling densities. The best available descriptor, assuming a minimum of 200 lodgepole pine snags per acre (500/ha) as a seed source, suggests that sites on azimuths between 290° and 45° at elevations between 6,500 and 6,800 ft (2 000 and 2 100 m) are likely to have 50,000 or more seedlings per acre (123 600/ha), while other sites below 7,000 ft (2 100 m) will have 10,000 to 20,000 seedlings per acre (24 700 to 49 400/ha), and sites above 7,000 ft less than 5,000 seedlings per acre (12 400/ha) (fig. 8a).

Changes in tree density will show an average attrition of 6 percent annually during the first decade for all initial densities greater than 10,000 per acre (24 700/ha). Where initial densities are no greater than 25,000 per acre (61 800/ha), this rate will drop to 3 percent for 20 additional years. At higher seedling densities, the attrition rate increases to 7.5 percent during the second and third postfire decades. If initial seedling densities are quite low, less than 10,000 per acre (24 700/ha), attrition will be a constant 3.5 percent for three decades, and for some very low initial seedling densities an increase may be recorded (fig. 8b).

In the absence of a better model, I suggest that lodgepole pine forests similar to the Sleeping Child Burn will normally have 3,500 to 8,000 dominant stems per acre (8 700 to 19 800/ha) at the end of the second decade, and that tree densities will eventually stabilize at no more than 5,000 to 6,000 stems per acre (12 400 to 14 800/ha).

Shrubs

Average shrub volumes leveled off at just over 2,000 ft^3 per acre (140 m^3/ha) between the sixth and eighth postfire years on the Sleeping Child Burn, but it was evident that stabilization occurred as a result of herbicide effects. Even a straight line projection of the growth required to reach nearly 4,000 ft^3 per acre (280 m^3/ha) between years 6 and 21 suggests that the average at the end of the first decade could have been at least 2,500 ft^3 per acre (175 m^3/ha). An even higher estimate can be derived from the fact that the majority of shrubs in these plant communities attained 50 percent of their eventual size in 6 years or less. A curvilinear extension of shrub volume changes after the sixth year suggests that an average as high as 3,000 ft^3 per acre (210 m^3/ha) at the end of the first decade would not have been unexpected.

However, any attempt to model shrub volumes on averages will prove somewhat deceiving. For the sample available in this study, the modal value is one-third lower than the mean; nearly half the transects had shrub volumes less than one-half the mean volume. If the 11 sites in this study are representative, over two-thirds of all shrub volume will normally develop on about one-fourth of the area. Mean shrub volumes on the remaining three-fourths will only be slightly greater than half the mean for all areas (fig. 8c).

Herbaceous Cover

Expressed in a general descriptive model for the Sleeping Child Burn, vascular herbaceous cover increased from 1 to 2 percent in the first postfire year to about 15 percent in year 3 and 20 to 25 percent in year 6. Thereafter, increments averaged less than 1 percent per year. Deviations from this pattern (fig. 8d) were related to tree densities. About 50 percent more vascular cover than average developed where tree densities were below 2,000 per acre (4 900/ha), and 50 percent less cover developed where tree densities exceeded 3,000 per acre (7 400/ha).

Nonvascular mosses and lichens exhibited a much slower rate of growth that did not begin until at least succession year 2 and may not have been important until years 5 and 6. In a generalized model (fig. 8e), development proceeded at a consistent 2 percent per year with 50 percent more nonvascular cover in dense tree stands and 50 percent less where tree densities were low.

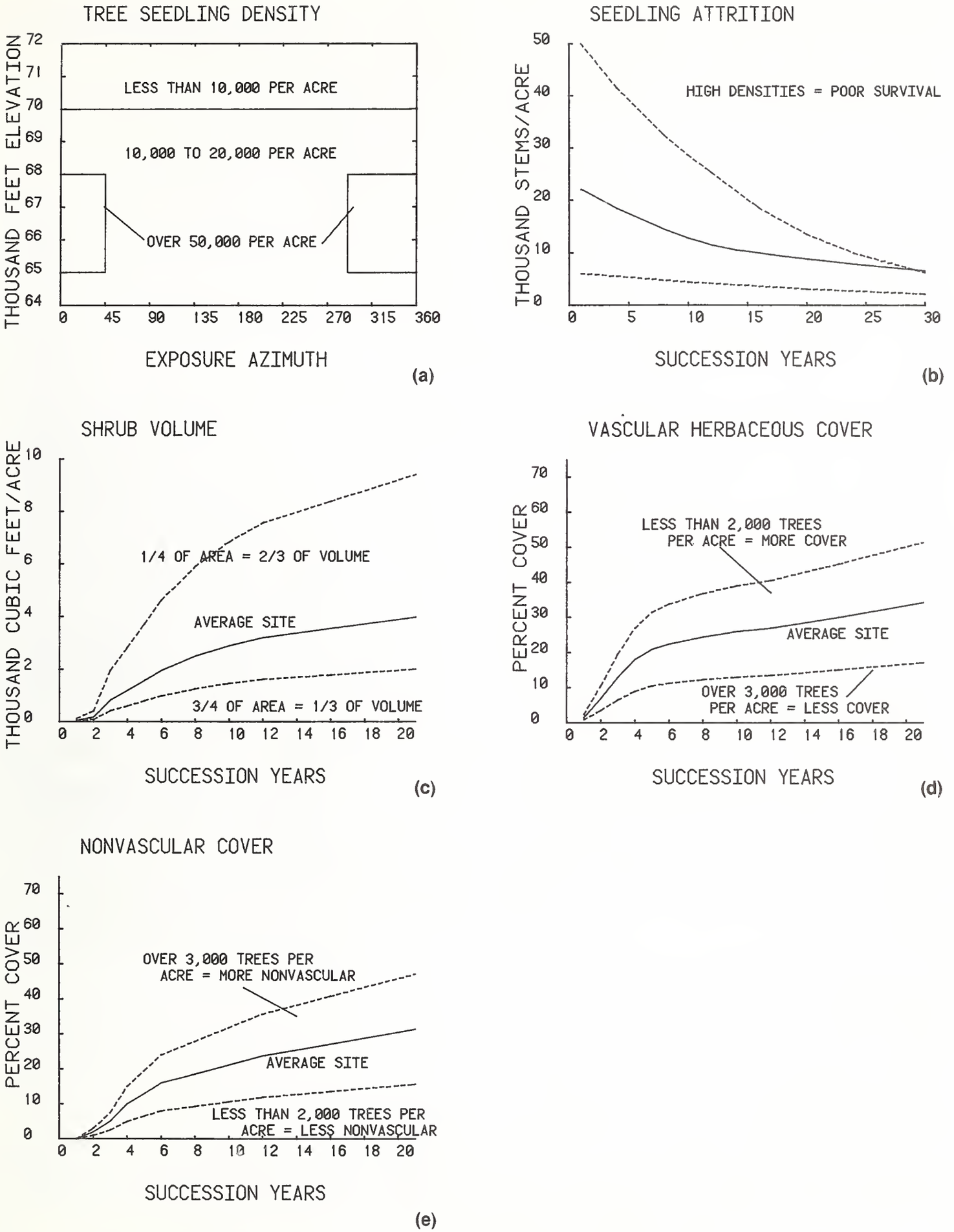

Figure 8.—Forest succession model: (a) tree seedling densities, (b) tree seedling attrition, (c) shrub volumes, (d) herbaceous cover, (e) nonvascular cover.

MANAGEMENT IMPLICATIONS

The succession model presented in this paper has several limitations that could prevent widespread application as a management tool. For example, extrapolation beyond the immediate vicinity of the Sleeping Child Burn clearly involves a substantial potential for error. In addition, similar results could not necessarily be expected for situations where the burned area is small and external seed sources could influence plant community development. However, with care in application, the model may have practical use in situations where lodgepole pine is the primary tree species of a burned area.

Available data proved to be somewhat of a disappointment in providing a method for predicting postfire tree seedling densities, but they do suggest two kinds of problem areas likely to be created by large fires. In areas above 7,000 ft (2 100 m), regeneration will almost certainly be inadequate. In areas below that elevation, tree densities will universally be so dense that some management action will be indicated. Favorable northerly aspects will be particularly troublesome.

In attempting to modify high tree densities, the experiences of the Bitterroot National Forest suggest that achieving acceptable timber management objectives is a more difficult problem than previously recognized. Of the several thinning methods tested in this burn, only direct cutting after about the 10th year seems to have been successful. On some sites, herbicide applications killed large numbers of trees, but none of the chemical treatments reduced tree densities to acceptable levels. While long-term side effects with herbicide treatments may have occurred, this could not be confirmed.

There were, however, some consistent patterns in the development of tree densities that might be helpful. On sites considered overstocked, long-term attrition of seedlings suggested a consistent leveling toward 5,000 to 6,000 stems per acre (12 400 to 14 800/ha) at about 30 years. This density is still far too high, but it was accompanied by establishment of dominance among live trees before the 10th postfire year. Because the number of trees over 18 inches (46 cm) tall did not increase substantially during the second decade, the opportune time to schedule timber stand improvement projects may be the end of the first decade, after dominance has been established.

If the Sleeping Child Burn is typical, only limited opportunity exists for manipulation of shrub communities with fire or as a part of postfire management. Virtually all the shrubs detected in the postburn community were present before the fire, and shrub volumes recorded after the fire were far lower than in unburned stands. Further, only two of the recorded shrub species recovered from burning at a rate commensurate with replacement of preburn volumes in less than 5 years. Among the shrub species expected to be dominant in mature forest communities, none recovered at a rate that would replace preburn volumes in less than a decade. The one response suggesting a potential for positive manipulation of shrubs was the increase in volume of species other than VASC when tree stands were thinned during the second decade. VASC did not respond favorably to disturbance of any kind.

Considering the relative weakness of the shrub component and the ubiquitous occurrence of VASC in these forest communities, the manager may have little apparent reason to attempt manipulation. At best, using prescribed fire as a tool, it may be possible to treat selected sites that are already dominated by shrubs and restore some vigor to existing decadent plants. Timber stand improvement thinnings could also increase shrub volume if such projects are delayed until at least the 10th postfire year. However, some care may be required in evaluating this response because substantial losses in VASC volume will accompany increases in other shrub species.

In the postfire period on a large burn, an immediate management concern is the potential for watershed damage. The Sleeping Child model suggests that, if live vegetation is the only criterion, there is reason for concern and little that can be done to alleviate it. These burned sites are considered vulnerable for at least the first 2 years. Thereafter, native vegetation will provide cover in the 10 to 15 percent range. Rehabilitation by aerial seeding will double ground cover during this early period, but the actual cover values will still be extremely low. During the first postfire growing season in this burn, live ground cover was less than 5 percent, but half of that was supplied by introduced species.

Finally, the model provides the manager a method of predicting rates at which snags will fall. This may be important in scheduling deadwood sales and firewood permits. In general, 25 percent of the usable snags will have fallen in 5 years, and 50 percent will be down in 10 years.

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APPENDIX: PLANT NAME ABBREVIATIONS USED

Trees:

PICO	*Pinus contorta* (lodgepole pine)
PSME	*Pseudotsuga menziesii* (Douglas-fir)

Shrubs:

ALSI	*Alnus sinuata*
AMAL	*Amelanchier alnifolia*
LOUT	*Lonicera utahensis*
LUSU	*Lupinus sulphureus*
MEFE	*Menziesia ferruginea*
RILA	*Ribes lacustre*
RIVI	*Ribes viscosissimum*
ROGY	*Rosa gymnocarpa*
SARA	*Sambucus racemosa*
SASC	*Salix scouleriana*
SHCA	*Shepherdia canadensis*
SOSC	*Sorbus scopulina*
SPBE	*Spiraea betulifolia*
SYOR	*Symphoricarpos oreophilus*
VAGL	*Vaccinium globulare*
VAMY	*Vaccinium myrtillus*
VASC	*Vaccinium scoparium*

Vascular herbaceous:

BRIN	*Bromus inermis*
CACO	*Carex concinnoides*
CAGE	*Carex geyeri*
CARO	*Carex rossii*
CARU	*Calamagrostis rubescens*
DAGL	*Dactylis glomerata*
EPAN	*Epilobium angustifolium*
FEOV	*Festuca ovina* var. *duriuscula*
PHPR	*Phleum pratense*
SECE	*Secale cereale*
TRRE	*Trifolium repens*
XETE	*Xerophyllum tenax*

Lyon, L. Jack. The Sleeping Child Burn—21 years of postfire change. Research Paper INT-330. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 17 p.

For 21 years following the Sleeping Child Burn of 1961, vegetation development was recorded on 11 permanent transects. Several cultural activities, including salvage logging, cattle grazing, and timber stand improvement thinning, influenced forest community development over short periods, but over a longer time we recorded a surprising stability and resilience in this lodgepole pine forest. Despite major modifications in plant community structure, it is possible to describe a consistent postfire successional pattern. A graphic model of postfire forest community development is presented.

KEYWORDS: fire, forest succession, herbicide side effects

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